

Lensing by Groups of Galaxies

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Abstract. A large fraction of known galaxy-lens systems require a component of external shear to explain the observed image geometries. In most cases, this shear can be attributed to a nearby group of galaxies. We discuss how the dark-matter mass distribution of groups of galaxies can influence the external shear for strongly lensed sources and calculate the expected weak lensing signal from groups for various mass profiles.

Most galaxies in the universe are neither in clusters nor isolated, but found in groups. To date, it is not known whether there exists a significant group dark-matter halo, similar to that for clusters of galaxies, or whether most of the matter is associated with the individual galaxies themselves. A recent weak-lensing study of a number of groups has shown that it is possible in principle to determine the mass profile of groups using their weak lensing signal (Hoekstra 1999). Because many models of strong lens systems require a substantial external shear to explain the observed image geometries and magnifications (Keeton, Kochanek & Seljak 1997, Kneib et al. 1998), we investigate how the dark matter distribution in a nearby group affects the external shear. We outline how both strong and weak gravitational lensing can be used to determine the mass distribution within groups of galaxies.

To investigate the gravitational lensing effect of groups we use a fast and accurate numerical ray-tracing code (Möller & Blain 1998, Blain, Möller & Maller 1999) and a group model based on PG115+080 (Keeton & Kochanek 1997). The lens PG115+080 consists of four galaxies separated by $\approx 10''$ with a total velocity dispersion of about 270 km s^{-1} . The group halo and galaxies are modelled as singular isothermal spheres (SISs). The group halo is assumed to be centred on the geometrical mean position of the group galaxies. We carried out simulations for different values of the group halo : individual galaxy mass ratio. Fig. 1(a) shows the expected radial profile of the reduced shear. There is a significant difference between a model in which all the mass is associated with the galaxies and models in which a significant fraction of the mass is in an intergalactic group halo. This will affect both the weak lensing distortions of background galaxies and the external shear contribution to any nearby strong galaxy lens. To test whether weak lensing observations can be used to distinguish these two different cases we simulated $100 \text{ } 60'' \times 60''$ fields at a resolution of $0.1''$, each containing 500 galaxies. The future Advanced Camera for Surveys (ACS) on the Hubble Space Telescope will have a field of view of similar size, a

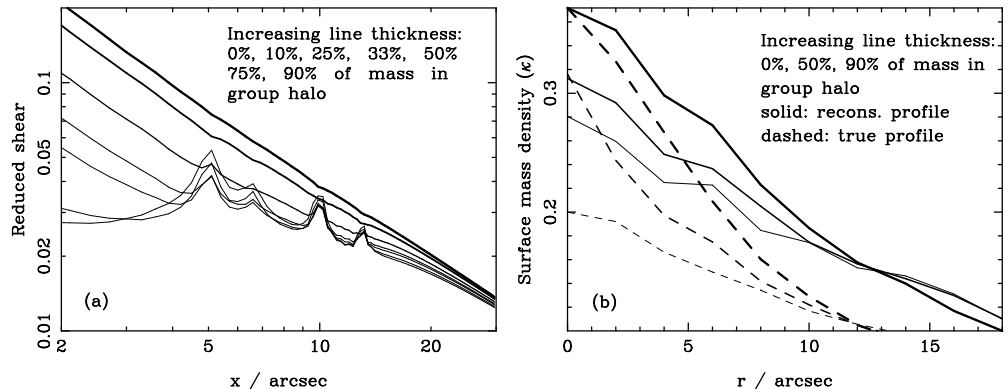


Figure 1. The effect of the mass distribution model on the lensing signal for various values of the group halo mass fraction. (a) The reduced shear as a function of radial distance from the group centre. (b) The weak lensing mass reconstruction from simulated observations and the theoretical profiles for three values of the group halo mass fraction.

resolution slightly below $0.1''$ and a sensitivity that will yield several hundreds of galaxies per square arc-minute in a few hours of integration. Fig. 1(b) shows the reconstructed mass profiles. For groups that have a massive group halo the mass profile is significantly steeper than for groups in which most mass is associated with the galaxies. The offset between the reconstructed and true mass profiles is due to the mass sheet degeneracy. The results show that it would be possible to distinguish between the different mass models with observations of this quality, which will be practical using ACS.

The external shear produced by a galaxy group depends significantly on the mass profile of the group. As most galaxies, and hence lenses, are likely to be part of a group, most lens models will need to take this effect into account. In the weak lensing regime, our results show that observations with new instruments, like the ACS, could differentiate between various group mass profiles.

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